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Deshpande et al.

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(54) **USER-SPECIFIC SEARCH OVER PROTECTED CONTEXTUAL DATA**

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G06F 17/30 (2006.01)
G06F 21/62 (2013.01)

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CPC ***G06F 17/30699*** (2013.01); ***G06F 17/30554*** (2013.01); ***G06F 21/6209*** (2013.01); ***G06F 21/6218*** (2013.01); ***G06F 21/6245*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30699; G06F 21/6209; G06F 21/6218; G06F 21/6245
See application file for complete search history.

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(57) **ABSTRACT**

Methods and arrangements for facilitating a display of search results. A search query is received from a user having a predetermined access level. A search is executed based on the search query and, based on the executed search, initial search results are produced. Sensitive information is redacted from the initial search results, based on the predetermined access level. The redacted search results are filtered and re-ordered to forestall an inference of the redacted sensitive information. The filtered and re-ordered search results are displayed to a user. Other variants and embodiments are broadly contemplated herein.

20 Claims, 5 Drawing Sheets

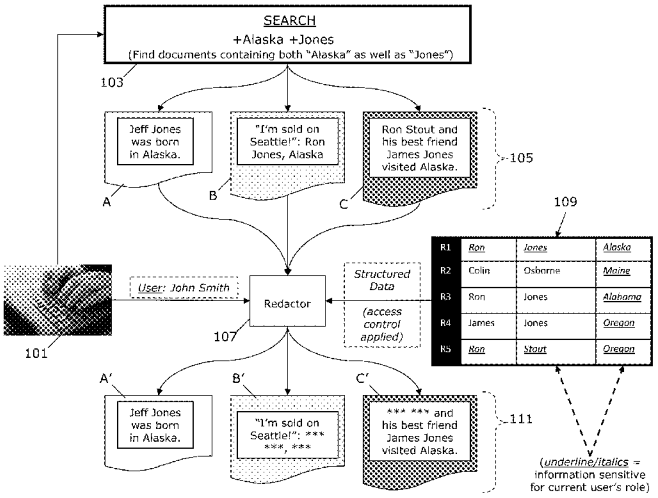
SEARCH
+Alaska +Jones
(Find documents containing both "Alaska" as well as "Jones")
103
Jeff Jones was born in Alaska.
"I'm sold on Seattle!": Ron Jones, Alaska
Ron Stout and his best friend James Jones visited Alaska.
105
A
B
C
109
R1 Ron Jones Alaska
R2 Colin Osborne Maine
R3 Ron Jones Alabama
R4 James Jones Oregon
R5 Ron Stout Oregon
User: John Smith
Redactor
Structured Data
(access control applied)
101
107
A'
B'
C'
Jeff Jones was born in Alaska.
"I'm sold on Seattle!": *** ***, ***
*** *** and his best friend James Jones visited Alaska.
111
(underline/italics = information sensitive for current user's role)

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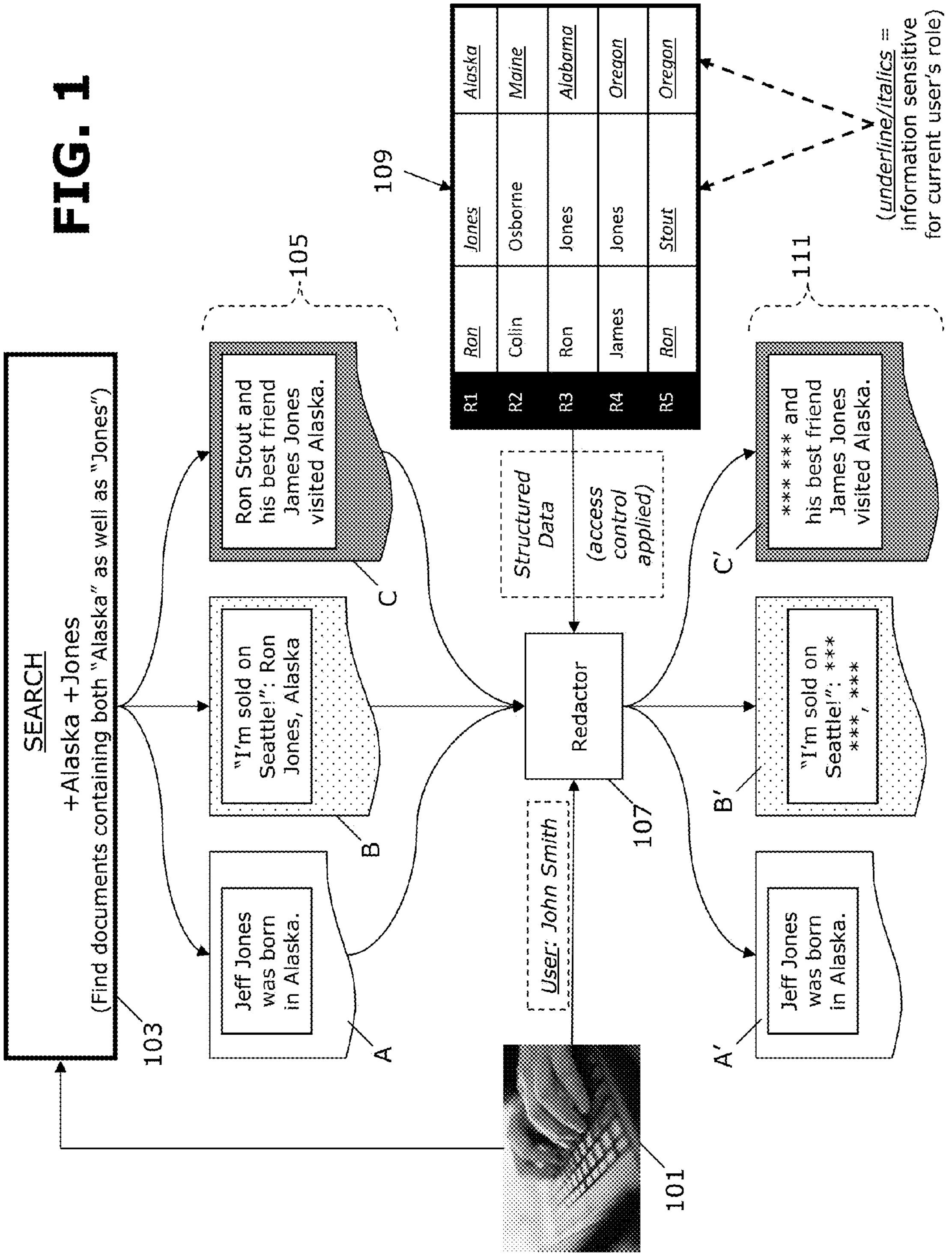
FIG. 1


SEARCH
+Alaska +Jones
(Find documents containing both "Alaska" as well as "Jones")
103
Jeff Jones was born in Alaska.
A
"I'm sold on Seattle!": Ron Jones, Alaska
B
Ron Stout and his best friend James Jones visited Alaska.
C
105
109
Structured Data
(access control applied)
Redactor
107
User: John Smith
101
Jeff Jones was born in Alaska.
A'
"I'm sold on Seattle!": *** ***, ***
B'
*** *** and his best friend James Jones visited Alaska.
C'
111
(underline/italics = information sensitive for current user's role)

R1	*Ron*	*Jones*	*Alaska*
R2	Colin	Osborne	*Maine*
R3	Ron	Jones	*Alabama*
R4	James	Jones	*Oregon*
R5	*Ron*	*Stout*	*Oregon*

```
Given, the user U and the query Q and a set of documents/records $\{d_1, d_2, ..., d_n\}$
Create a binary formula $B_Q$ for Q
for d $\epsilon$ $S_Q$ do                    % $S_Q$ is the set of documents in the search result
    for $t_i$ $\epsilon$ Q do                % $t_i$ are the terms in the original query Q
        if $t_i$ $\epsilon$ d then               % track the terms which existed in the document
            $b_i$ ← TRUE
        else
            $b_i$ ← FALSE
        end if
    end for
    for $t_i$ $\epsilon$ Q do
        if $t_i$ $\epsilon$ $R_U^d$ then        % $R_U^d$ is the set of terms redacted from document d for user U
                $b_i$ ← FALSE
        end if
    end for
    if $B_Q$ == TRUE then
        $S_Q^U \leftarrow S_Q^U$ □ $d^U$          % Add $d^U$ to the set of 'valid' documents which should be visible to the user
    else
        continue                             %Hide the redacted document/record $d^U$ from user U
    end if
end for
Reorder $S_Q^U$ as per the default ranking formula
```

213

FIG. 2

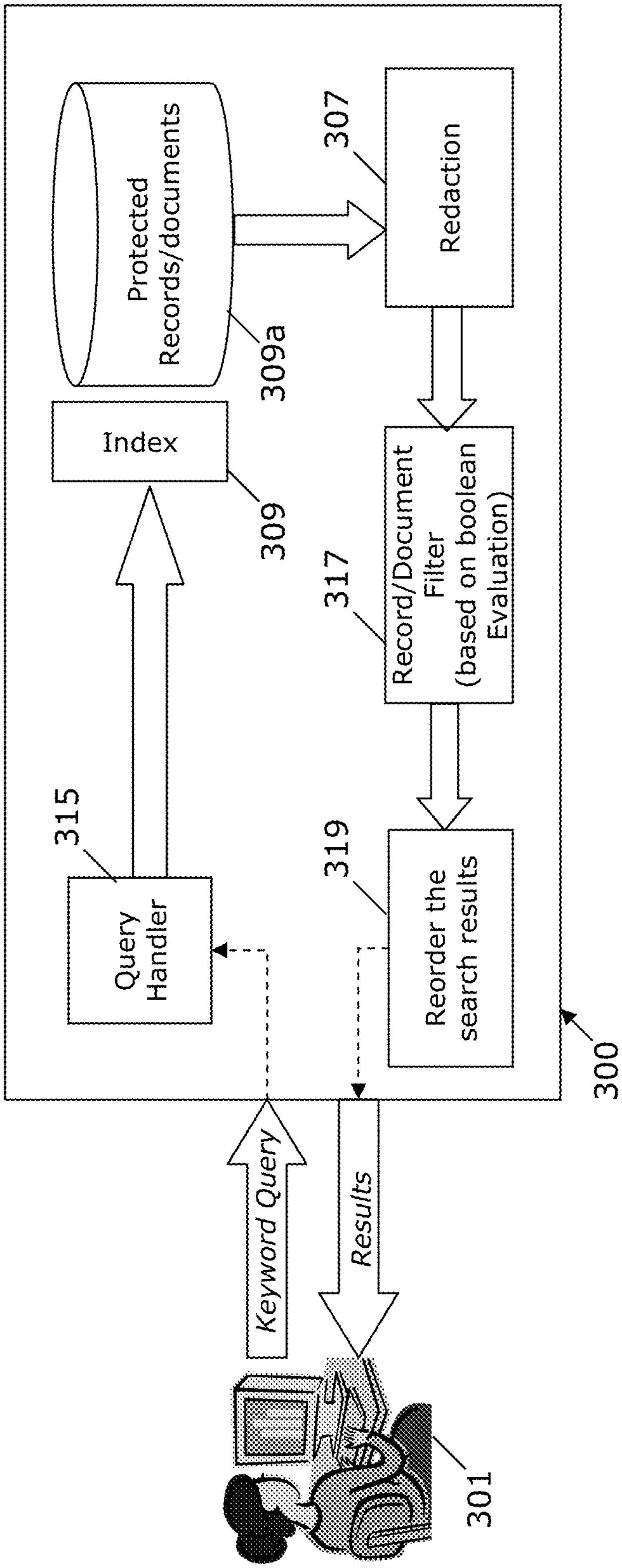

Protected Records/documents
309a
Redaction
307
Index
309
Record/Document Filter (based on boolean Evaluation)
317
Query Handler
315
Reorder the search results
319
300
Keyword Query
Results
301

FIG. 3

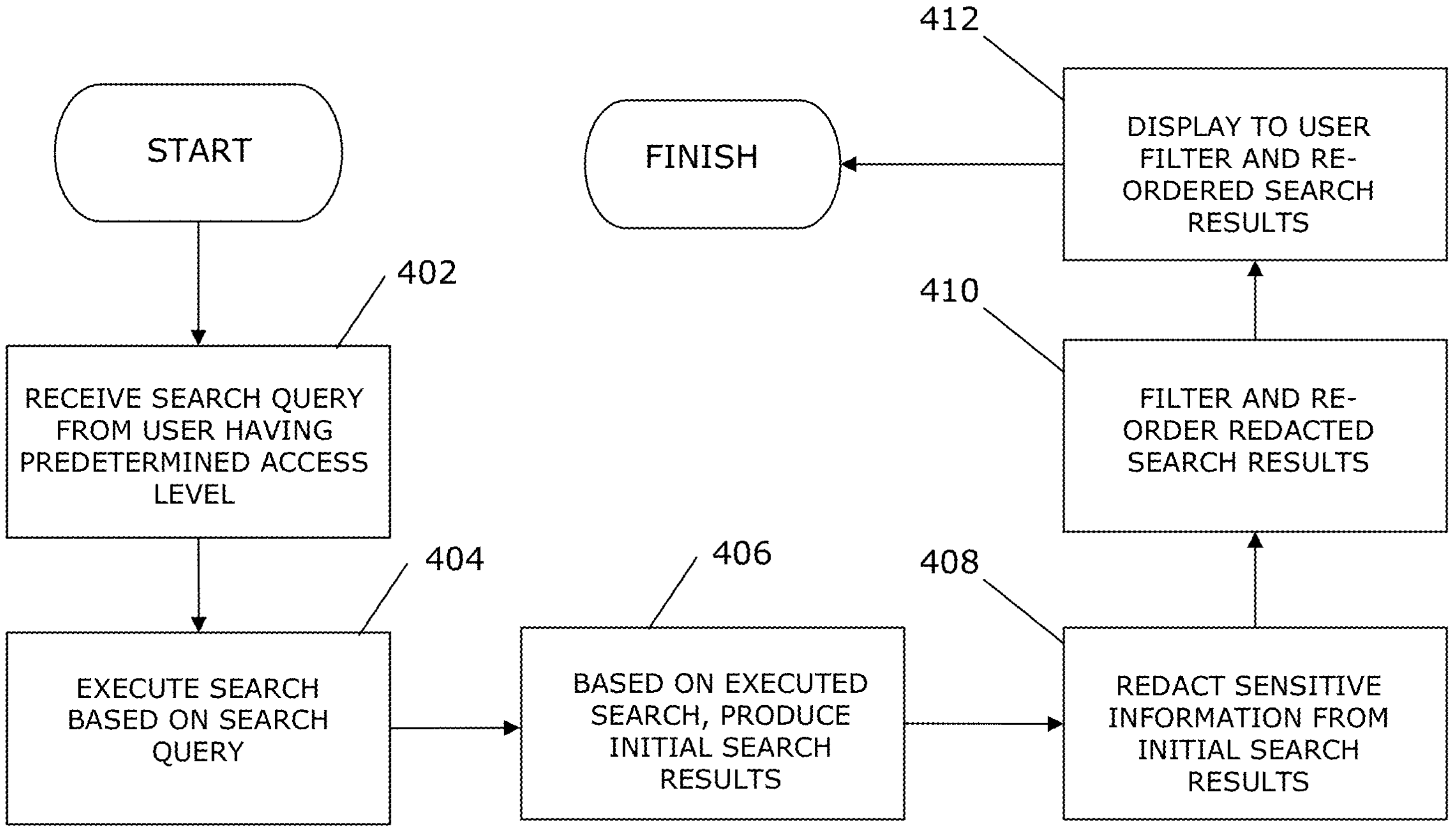

START
402
RECEIVE SEARCH QUERY FROM USER HAVING PREDETERMINED ACCESS LEVEL
404
EXECUTE SEARCH BASED ON SEARCH QUERY
406
BASED ON EXECUTED SEARCH, PRODUCE INITIAL SEARCH RESULTS
408
REDACT SENSITIVE INFORMATION FROM INITIAL SEARCH RESULTS
410
FILTER AND RE-ORDER REDACTED SEARCH RESULTS
412
DISPLAY TO USER FILTER AND RE-ORDERED SEARCH RESULTS
FINISH

FIG. 4

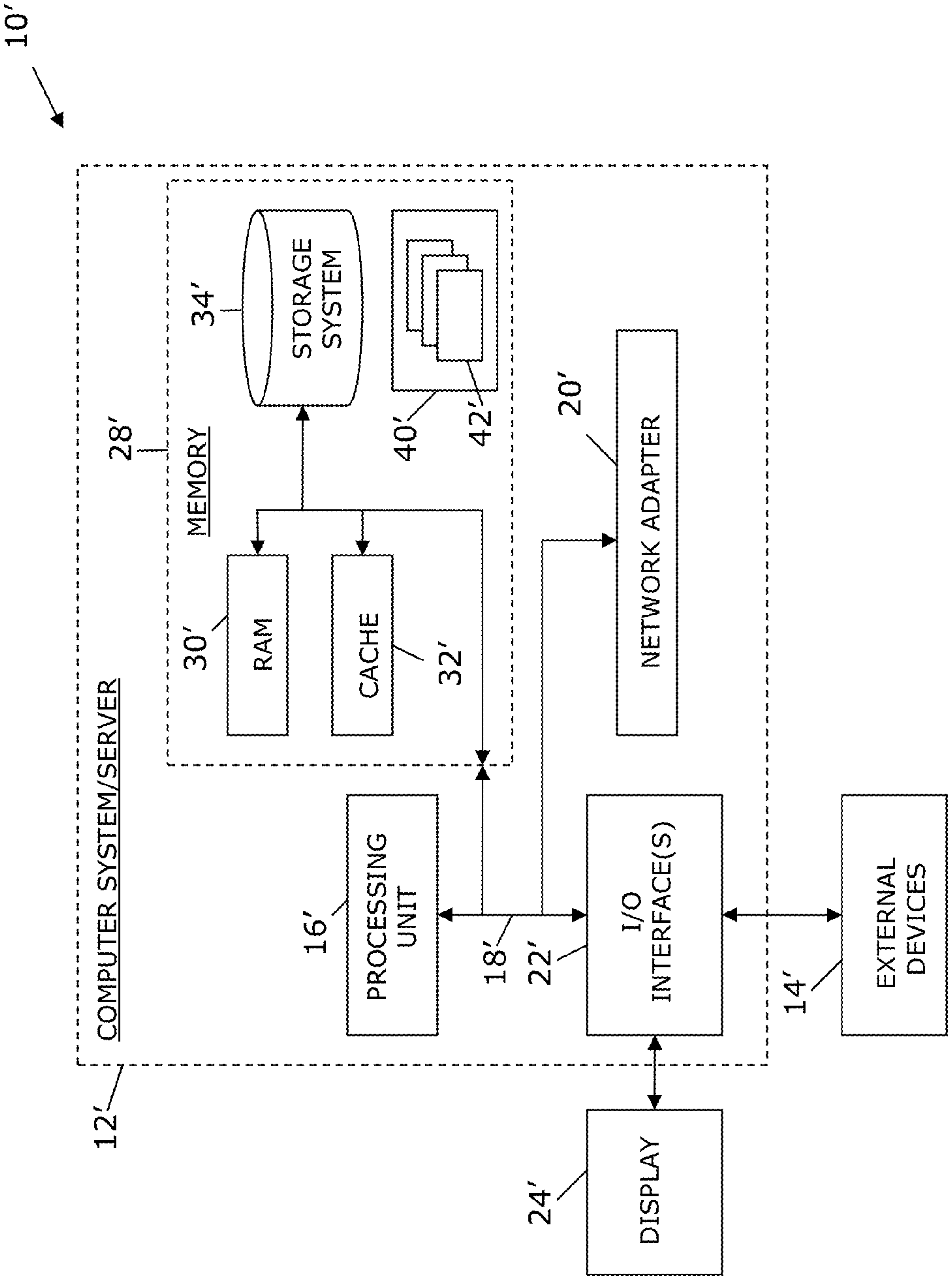

10′
COMPUTER SYSTEM/SERVER
12′
MEMORY
28′
STORAGE SYSTEM
34′
40′
42′
RAM
30′
CACHE
32′
NETWORK ADAPTER
20′
PROCESSING UNIT
16′
18′
I/O INTERFACE(S)
22′
EXTERNAL DEVICES
14′
DISPLAY
24′

FIG. 5

USER-SPECIFIC SEARCH OVER PROTECTED CONTEXTUAL DATA

BACKGROUND

Generally, contextual information relating to business or other entities could be present in structured sources as well as documents. Access control and redaction mechanisms are typically used to protect this information.

On structured data, label-based access control can be used to define the policies that govern access. Similar policies can be enforced on unstructured data, by identifying sensitive data based on the user accessing the document and redacting it. However, keyword searching on such protected data can lead to an inadvertent leakage of information, even if sensitive information is hidden in the results.

BRIEF SUMMARY

In summary, one aspect of the invention provides a method of facilitating a display of search results, the method comprising: utilizing at least one processor to execute computer code configured to perform the steps of: receiving a search query from a user having a predetermined access level; executing a search based on the search query; producing initial search results based on the executed search; redacting sensitive information from the initial search results based on the predetermined access level; filtering and re-ordering the redacted search results to forestall an inference of the redacted sensitive information; and displaying to a user the filtered and re-ordered search results.

Another aspect of the invention provides an apparatus for facilitating a display of search results, the apparatus comprising: at least one processor; and a computer readable storage medium having computer readable program code embodied therewith and executable by the at least one processor, the computer readable program code comprising: computer readable program code configured to receive a search query from a user having a predetermined access level; computer readable program code configured to execute a search based on the search query; computer readable program code configured to produce initial search results based on the executed search; computer readable program code configured to redact sensitive information from the initial search results based on the predetermined access level; computer readable program code configured to filter and re-order the redacted search results to forestall an inference of the redacted sensitive information; and computer readable program code configured to display to a user the filtered and re-ordered search results.

An additional aspect of the invention provides a computer program product for facilitating a display of search results, the computer program product comprising: a computer readable storage medium having computer readable program code embodied therewith, the computer readable program code comprising: computer readable program code configured to receive a search query from a user having a predetermined access level; computer readable program code configured to execute a search based on the search query; computer readable program code configured to produce initial search results based on the executed search; computer readable program code configured to redact sensitive information from the initial search results based on the predetermined access level; computer readable program code configured to filter and re-order the redacted search results to forestall an inference of the redacted sensitive information; and computer readable program code configured to display to a user the filtered and re-ordered search results.

A further aspect of the invention provides a method comprising: receiving a search query from a user with a given access level; executing a search based on the search query; producing search results which omit information relative to the user's access level and which re-order the search results to forestall inference of missing information; the producing comprising: identifying at least one keyword for redaction from the search query, and redacting the at least one keyword from at least one document of the search results; and setting a boolean literal of a search term to true if the search term is present in at least one document of the search results, else setting the boolean literal to false.

For a better understanding of exemplary embodiments of the invention, together with other and further features and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying drawings, and the scope of the claimed embodiments of the invention will be pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** illustrates execution of a search.

FIG. **2** provides a redacting algorithm.

FIG. **3** provides a general flow diagram for a keyword-based retrieval system.

FIG. **4** sets forth a process more generally for facilitating a display of search results.

FIG. **5** illustrates a computer system.

DETAILED DESCRIPTION

It will be readily understood that the components of the embodiments of the invention, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations in addition to the described exemplary embodiments. Thus, the following more detailed description of the embodiments of the invention, as represented in the figures, is not intended to limit the scope of the embodiments of the invention, as claimed, but is merely representative of exemplary embodiments of the invention.

Reference throughout this specification to "one embodiment" or "an embodiment" (or the like) means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" or the like in various places throughout this specification are not necessarily all referring to the same embodiment.

Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in at least one embodiment. In the following description, numerous specific details are provided to give a thorough understanding of embodiments of the invention. One skilled in the relevant art may well recognize, however, that embodiments of the invention can be practiced without at least one of the specific details thereof, or can be practiced with other methods, components, materials, et cetera. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

The description now turns to the figures. The illustrated embodiments of the invention will be best understood by reference to the figures. The following description is intended only by way of example and simply illustrates certain selected exemplary embodiments of the invention as claimed herein.

It should be noted that the flowchart and block diagrams in the figures illustrate the architecture, functionality, and operation of possible implementations of systems, apparatuses, methods and computer program products according to various embodiments of the invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises at least one executable instruction for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

Specific reference will now be made herebelow to FIGS. **1**-**3**. It should be appreciated that the processes, arrangements and products broadly illustrated therein can be carried out on, or in accordance with, essentially any suitable computer system or set of computer systems, which may, by way of an illustrative and non-restrictive example, include a system or server such as that indicated at **12'** in FIG. **5**. In accordance with an example embodiment, most if not all of the process steps, components and outputs discussed with respect to FIGS. **1**-**3** can be performed or utilized by way of a processing unit or units and system memory such as those indicated, respectively, at **16'** and **28'** in FIG. **5**, whether on a server computer, a client computer, a node computer in a distributed network, or any combination thereof.

Broadly contemplated herein, in accordance with at least one embodiment of the invention, are methods and arrangements which prevent information leakage, as described further above, with minimal overhead in the context of a system.

Generally, in accordance with a context of at least one embodiment of the invention, a search engine (via the Internet, or offline) gathers results based on a supplied query. A query is made up of one or more terms (i.e., keywords) with optional search directives (such as "and"/"or", possibly including "-" to exclude a term from the results). To control the information in the query results based on any access rights of the user querying the system, a document redactor can be employed to mask the sensitive information for unstructured data. (For background purposes, an example of such a redactor can be found in U.S. Pat. No. 7,831,571 to Roy et al.) Returning these redacted documents/records to the user without further filtering can lead to potential information leakage.

By way of a non-restrictive example illustrating a context of at least one embodiment of the invention, FIG. **1** illustrates a search being executed. As shown, a user at a computer (**101**) executes a search **103** to find documents containing both of the terms "Alaska" and "Jones". An initial set of results **105** is yielded; just three (A, B, C) are shown here for ease of illustration. Some of the results contain information sensitive for a current user's role, and a redactor **107** serves to sanitize the results, by applying access control as determined by an index of structured data **109**, to create an updated set of results **111**. In this updated set, sensitive information is blocked out while still permitting the user to see the rest of the document. Sensitive information, as broadly contemplated and discussed herein, can include, inter alia, any information that one or more users with a given predetermined access level does not have permission to view. By way of an illustrative and non-restrictive example, such sensitive information could include be sensitive medical information, such "protected health information" (PHI) relating to a medical patient.

Thus, in accordance with the present example, in accordance with a context of at least one embodiment of the invention, the redactor **107** is made aware of user "John Smith". In consulting the structured data **109**, it is determined that with regard to several individuals (here, with regard to all five records, R**1**-R**5**, shown in the table of data **109**), information on anyone's state of residence is off limits to user John Smith. Further, it is determined that even the names "Ron Jones" (of Alaska) and "Ron Stout" (of Oregon) are off-limits to user Smith. Accordingly, the redactor **107** produces updated results **111**. As shown, updated result A' remains intact while "Ron Jones" and "Alaska" are redacted out from result B'. For result C', "Ron Stout" is redacted out.

In accordance with the present example, in accordance with a context of at least one embodiment of the invention, it can be appreciated that sensitive information (for user John Smith) indeed is redacted out successfully. However, it can also be appreciated that in reviewing the results as a whole, it may still be possible for user Smith to make reasonable inferences about information missing from one updated result (B', C') or another. This may be regarded as a form of "information leakage", which methods and arrangements broadly contemplated herein aim to address.

Generally, in accordance with a context of at least one embodiment of the invention, consider a query "term**1** AND term**2**" (i.e., +term**1** +term**2**). In an initial harvesting of results, all the documents/records which satisfy this query will be returned. Accordingly, for the purposes of illustration consider that term**1** is sensitive, and is accordingly redacted/blocked from documents in the search results. Thus, when the user reads the documents (or records), (s)he can deduce the presence of term**1** since it was a mandatory term in the query; this indeed can represent a form of information leakage.

Generally, in accordance with a context of at least one embodiment of the invention, let Q represent a query, composed of terms $t_1, t_2, \ldots, t_k$. For example: Q=(t_1 AND (t_2 OR t_5)) OR t_6. Let the documents/records present in the system be $D=\{d_1, d_2, \ldots, d_n\}$. For the query Q, a subset of documents, S_Q will match: $S_Q=\{d_i | d_i \text{ satisfies } Q\}$. Next, a step of redaction filters out certain terms R_U^d from a document/record d based on the role of the user U, where:

$$R_U^{d}=\{t_i|(t_i \epsilon d)\hat{}(t_i \text{ is restricted for } U)\}.$$

Then, let $D^U=\{d_1^U, d_2^U, \ldots, d_n^U\}$, where $d_i^U=d_i-R_U^d$, i.e., D^U is the database that the user is permitted to see.

Generally, in accordance with a context of at least one embodiment of the invention, a query Q by a user U should be matched against D^U. However, this is inefficient since D^U depends on the user U that is specified at runtime. This makes it difficult to index D^U beforehand. A naïve approach may thus involve simply applying the redaction/filtering on the results over D, i.e., on S_Q. However, this can lead to at least one form of information leakage, as touched on above.

FIG. **2** provides a redacting algorithm **213**, in accordance with at least one embodiment of the invention. As such, there is constructed a binary logic formula B_Q which is equivalent to Q and in which each original term t_i is represented as a boolean literal b_i. For example, the earlier query Q can be represented as: $B_Q=(b_1\hat{}(b_2 v b_5))v b_6$. For a document/record d in the query result set, there are identified the redacted keywords R_U^d and form the redacted document d^U. If a term t_i was present in d, i.e., $t_i \epsilon d$, b_i is set to TRUE, else it is set to FALSE. If a term t_i in Q was redacted from the document/record, i.e., $t_i \epsilon R_U^d$, the corresponding b_i is set to FALSE. If B_Q now evaluates to TRUE, the redacted document d^U is added to the final set, S_Q^U, else its existence is hidden. S_Q^U is then re-ordered using a default ranking formula, as already used by the base search algorithm, to avoid any inference. It can be shown that S_Q^U is equivalent of running Q on D^U.

FIG. **3** provides a general flow diagram for a keyword-based retrieval system **300**, in accordance with at least one embodiment of the invention. As shown, a computer-based user **301** can send a keyword query to the system **300** and its query handler **315**. An index **309** to protected records/documents **309***a* is then consulted, and a redaction step **307** takes place similarly to the example of FIG. **1**. However, at this point, a record/document filter **317** acts to apply the binary logic formula discussed above, and the search results are reordered (**319**), as also discussed above.

FIG. **4** sets forth a process more generally for facilitating a display of search results, in accordance with at least one embodiment of the invention. It should be appreciated that a process such as that broadly illustrated in FIG. **4** can be carried out on essentially any suitable computer system or set of computer systems, which may, by way of an illustrative and non-restrictive example, include a system such as that indicated at **12'** in FIG. **5**. In accordance with an example embodiment, most if not all of the process steps discussed with respect to FIG. **4** can be performed by way of a processing unit or units and system memory such as those indicated, respectively, at **16'** and **28'** in FIG. **5**.

As shown in FIG. **4**, in accordance with at least one embodiment of the invention, a search query is received from a user having a predetermined access level (**402**). A search is executed based on the search query (**404**) and, based on the executed search, initial search results are produced (**406**). Sensitive information is redacted from the initial search results, based on the predetermined access level (**408**). The redacted search results are filtered and re-ordered to forestall an inference of the redacted sensitive information (**410**). The filtered and re-ordered search results are displayed to a user (**412**).

Referring now to FIG. **5**, a schematic of an example of a cloud computing node is shown. Cloud computing node **10'** is only one example of a suitable cloud computing node and is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the invention described herein. Regardless, cloud computing node **10'** is capable of being implemented and/or performing any of the functionality set forth hereinabove. In accordance with embodiments of the invention, computing node **10'** may not necessarily even be part of a cloud network but instead could be part of another type of distributed or other network, or could represent a stand-alone node. For the purposes of discussion and illustration, however, node **10'** is variously referred to herein as a "cloud computing node".

In cloud computing node **10'** there is a computer system/server **12'**, which is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with computer system/server **12'** include, but are not limited to, personal computer systems, server computer systems, thin clients, thick clients, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputer systems, mainframe computer systems, and distributed cloud computing environments that include any of the above systems or devices, and the like.

Computer system/server **12'** may be described in the general context of computer system-executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **12'** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in both local and remote computer system storage media including memory storage devices.

As shown in FIG. **5**, computer system/server **12'** in cloud computing node **10** is shown in the form of a general-purpose computing device. The components of computer system/server **12'** may include, but are not limited to, at least one processor or processing unit **16'**, a system memory **28'**, and a bus **18'** that couples various system components including system memory **28'** to processor **16'**.

Bus **18'** represents at least one of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

Computer system/server **12'** typically includes a variety of computer system readable media. Such media may be any available media that are accessible by computer system/server **12'**, and include both volatile and non-volatile media, removable and non-removable media.

System memory **28'** can include computer system readable media in the form of volatile memory, such as random access memory (RAM) **30'** and/or cache memory **32'**. Computer system/server **12'** may further include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **34'** can be provided for reading from and writing to a non-removable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk"), and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to bus **18'** by at least one data media interface. As will be further depicted and described below, memory **28'** may include at least one program product having a set (e.g., at least one) of program modules that are configured to carry out the functions of embodiments of the invention.

Program/utility **40'**, having a set (at least one) of program modules **42'**, may be stored in memory **28'** (by way of example, and not limitation), as well as an operating system, at least one application program, other program modules, and program data. Each of the operating systems, at least one application program, other program modules, and program data or some combination thereof, may include an implementation of a networking environment. Program modules **42'** generally carry out the functions and/or methodologies of embodiments of the invention as described herein.

Computer system/server **12'** may also communicate with at least one external device **14'** such as a keyboard, a pointing device, a display **24'**, etc.; at least one device that enables a user to interact with computer system/server **12**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **12'** to communicate with at least one other computing device. Such communication can occur via

I/O interfaces **22'**. Still yet, computer system/server **12'** can communicate with at least one network such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **20'**. As depicted, network adapter **20'** communicates with the other components of computer system/server **12'** via bus **18'**. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **12'**. Examples include, but are not limited to: microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

It should be noted that aspects of the invention may be embodied as a system, method or computer program product. Accordingly, aspects of the invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the invention may take the form of a computer program product embodied in at least one computer readable medium having computer readable program code embodied thereon.

Any combination of one or more computer readable media may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having at least one wire, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store, a program for use by, or in connection with, an instruction execution system, apparatus, or device.

A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wire line, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

Computer program code for carrying out operations for aspects of the invention may be written in any combination of at least one programming language, including an object oriented programming language such as Java®, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer (device), partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer, or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Aspects of the invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture. Such an article of manufacture can include instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

This disclosure has been presented for purposes of illustration and description but is not intended to be exhaustive or limiting. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiments were chosen and described in order to explain principles and practical application, and to enable others of ordinary skill in the art to understand the disclosure.

Although illustrative embodiments of the invention have been described herein with reference to the accompanying drawings, it is to be understood that the embodiments of the invention are not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the disclosure.

What is claimed is:

1. A method of facilitating a display of search results, said method comprising:

utilizing at least one processor to execute computer code configured to perform the steps of:

receiving a search query from a user having a predetermined access level;

executing a search based on the search query;

producing initial search results based on the executed search;

redacting sensitive information from the initial search results based on the predetermined access level;

filtering and re-ordering the redacted search results to forestall an inference of the redacted sensitive information; and

displaying to a user the filtered and re-ordered search results.

2. The method according to claim **1**, wherein said filtering and re-ordering comprises re-ranking the redacted search results relative to a base search algorithm associated with said executing.

3. The method according to claim **1**, wherein said filtering and re-ordering comprises constructing a binary logic formula corresponding to the search query.

4. The method according to claim **3**, wherein:

the search query comprises at least one search term;

said constructing comprising representing each of the least one search term as a boolean literal.

5. The method according to claim **4**, wherein:

the initial search results comprise at least one document; and

the redacted search results comprise at least one redacted document corresponding to at least one document from the initial search results.

6. The method according to claim **5**, wherein said redacting comprises identifying at least one keyword for redaction from the search query, and redacting the at least one keyword from at least one document of the initial search results.

7. The method according to claim **6**, wherein said filtering and re-ordering comprises setting a boolean literal of a search term to true if the search term is present in at least one document of the initial search results, else setting the boolean literal to false.

8. The method according to claim **7**, wherein said filtering and re-ordering comprises setting a boolean literal of a search term from the search query to false if the search term is redacted from the initial search results.

9. The method according to claim **8**, wherein said filtering and re-ordering comprises:

evaluating the binary logic formula; and

adding a redacted document to the redacted search results if the binary logic formula evaluates to true.

10. The method according to claim **9**, wherein said filtering and re-ordering comprises hiding the redacted document from the redacted search results if the binary logic formula evaluates to false.

11. An apparatus for facilitating a display of search results, said apparatus comprising:

at least one processor; and

a computer readable storage medium having computer readable program code embodied therewith and executable by the at least one processor, the computer readable program code comprising:

computer readable program code configured to receive a search query from a user having a predetermined access level;

computer readable program code configured to execute a search based on the search query;

computer readable program code configured to produce initial search results based on the executed search;

computer readable program code configured to redact sensitive information from the initial search results based on the predetermined access level;

computer readable program code configured to filter and re-order the redacted search results to forestall an inference of the redacted sensitive information; and

computer readable program code configured to display to a user the filtered and re-ordered search results.

12. A computer program product for facilitating a display of search results, said computer program product comprising:

a computer readable storage medium having computer readable program code embodied therewith, the computer readable program code comprising:

computer readable program code configured to receive a search query from a user having a predetermined access level;

computer readable program code configured to execute a search based on the search query;

computer readable program code configured to produce initial search results based on the executed search;

computer readable program code configured to redact sensitive information from the initial search results based on the predetermined access level;

computer readable program code configured to filter and re-order the redacted search results to forestall an inference of the redacted sensitive information; and

computer readable program code configured to display to a user the filtered and re-ordered search results.

13. The computer program product according to claim **12**, wherein said filtering and re-ordering comprises re-ranking the redacted search results relative to a base search algorithm associated with said executing.

14. The computer program product according to claim **12**, wherein said filtering and re-ordering comprises constructing a binary logic formula corresponding to the search query.

15. The computer program product according to claim **14**, wherein:

the search query comprises at least one search term;

said constructing comprising representing each of the least one search term as a boolean literal.

16. The computer program product according to claim **15**, wherein:

the initial search results comprise at least one document; and

the redacted search results comprise at least one redacted document, corresponding to at least one document from the initial search results.

17. The computer program product according to claim **16**, wherein said redacting comprises identifying at least one keyword for redaction from the search query, and redacting the at least one keyword from at least one document of the initial search results.

18. The computer program product according to claim **17**, wherein said filtering and re-ordering comprises setting a boolean literal of a search term to true if the search term is present in at least one document of the initial search results, else setting the boolean literal to false.

19. The computer program product according to claim **18**, wherein said filtering and re-ordering comprises setting a boolean literal of a search term from the search query to false if the search term is redacted from the initial search results.

20. A method comprising:

receiving a search query from a user with a given access level;

executing a search based on the search query;

producing search results which omit information relative to the user's access level and which re-order the search results to forestall inference of missing information;

said producing comprising:

identifying at least one keyword for redaction from the search query, and redacting the at least one keyword from at least one document of the search results; and setting a boolean literal of a search term to true if the search term is present in at least one document of the search results, else setting the boolean literal to false.

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